national accelerator laboratory

EXP. 55

ACCELERATOR EXPERIMENT - - Long Pulse Performance of Linac and Booster

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Because of the relatively low intensity of H^- ion sources, negative ion injection into the booster requires many turns, at least 50-100, in order to compete favorably with proton injection of a few turns. Whereas one always operates with a proton-beam pulse of less than 12 μsec for multiturn injection into the booster, one requires a pulse length of 150-300 μsec with an H^- beam. The object of the measurement reported here was to determine what problems might exist for long-pulse operation.

The linac quads are pulsed with a sine-wave-type current giving a 2.7% droop in quad field at the ends of a 300-μsec pulse centered at the peak of the field. This can lead to shifts in beam momentum and emittance which affect booster capture. Last March a measurement was made to test the effect on linac beam momentum and on accelerated booster beam at the 45-mA level as the linac quad pulse was delayed in time. That test indicated, for a short injected beam pulse, that the accelerated booster beam when averaged over a 300-μsec time internal of the linac quads was approximately 75% of the maximum value.

Another factor affecting capture of beam in the booster for a long pulse is the shift in equilibrium orbit, which becomes significant for a small effective aperture.

The linac's rf-design-pulse length is 400 μsec, although normal operation does not require this length. At the time of this experiment, a limitation existed on the tuning range of tank #1 so that the rf-pulse length of system #1 was limited. Our beam-pulse length was, therefore, limited to 140 μsec.

The linac-rf timing was shifted in time relative to the booster magnet field to provide a beam pulse that was believed to start 50 μsec before minimum field and end 90 μsec after minimum field. An uncertainty of ~ 50 μsec existed in the time of minimum field. A 9-μsec chop, giving over three turns of injection, sampled the 140-μsec beam pulse from one end to the other. The beam intensity was measured at injection and at 8 GeV to give booster transmission at various times during the long pulse.

To make acceleration possible at these times one varied five triggers simultaneously through a multiple-5 connection: chopper time on and off, septum 1, septum 2, and orbit bump.

When the beam intensity from the ion source and linac was reduced from the nominal 80-mA level, no retuning of the 750-keV or the 200-MeV transport lines was carried out to adapt to the altered optics of the low intensity beams. During this period of time, the ion source ran at reduced gas pressure, as it had for several days to protect the ion pump. As a consequence there was a pronounced droop in the ion-source current during the long pulse. Because of all of these conditions, the match to the booster was almost certainly less favorable than one could expect to achieve by consciously tuning for a long pulse beam.

Observations

Three runs were made using different beam currents from the linac. The first beam was obtained by shifting the phase of the buncher 180° to reduce the beam intensity by a factor of four and by turning down the ion-source magnet to reach a low linac-beam current, which varied from roughly 10 mA to 5 mA during the pulse. The beam current pulse at the input and exit of the linac is shown in Fig. 1. Because there is a several kilovolt droop in the preaccelerators voltage at high current in the absence of a bouncer, another beam was provided by phasing the buncher for maximum bunching and reducing the source intensity much further. This procedure gave the beam pulse of nominally 10 mA in Fig. 2, having somewhat less droop. Finally a third beam pulse of nominally 20 mA, shown in Fig. 3, was provided by turning up the source intensity.

The transmission of the booster as a function of time during the beam pulse is shown in Fig. 4 for each of the three runs. The principal result is the fact that the transmission held up throughout the long pulse; in fact, it increased at later time. For high intensity operation (80 mA from the linac), the best transmission for a 9-μsec chop has been 20-24%. For the low intensity beams here, the transmission has increased somewhat over this value, without benefit of tuning to improve the match to the booster.

The reduced momentum spread of the low intensity beam probably contributed to improved transmission. Although not measured very accurately, this momentum spread is also shown in Fig. 4. There appears to be some correlation between $\Delta p/p$ and transmission in terms of variation during the pulse and during the change from one beam to the other.

Two samples of linac-momentum spread from the single-wire scanner are shown in Figures 5 and 6 at the approximate midpoint of the beam pulse.

There was some shift in momentum of the linac beam during the pulse as shown in Fig. 7. Also plotted in Fig. 7 is transmission of the 200-MeV transport line for the three beams. No measurements of beam emittance were made.

Conclusion

There appear no significant problems in running with a beam pulse up to at least 140 μsec long at currents of 5 to 20 mA. The booster transmission (20-30%) is at least as good or better at all parts of the pulse for a three-turn chop as for a short three-turn pulse at high intensity. It is anticipated that the small variations observed during the pulse will be somewhat reduced with the ion source operated in its normal pressure range to maintain a more nearly uniform beam current during the pulse.

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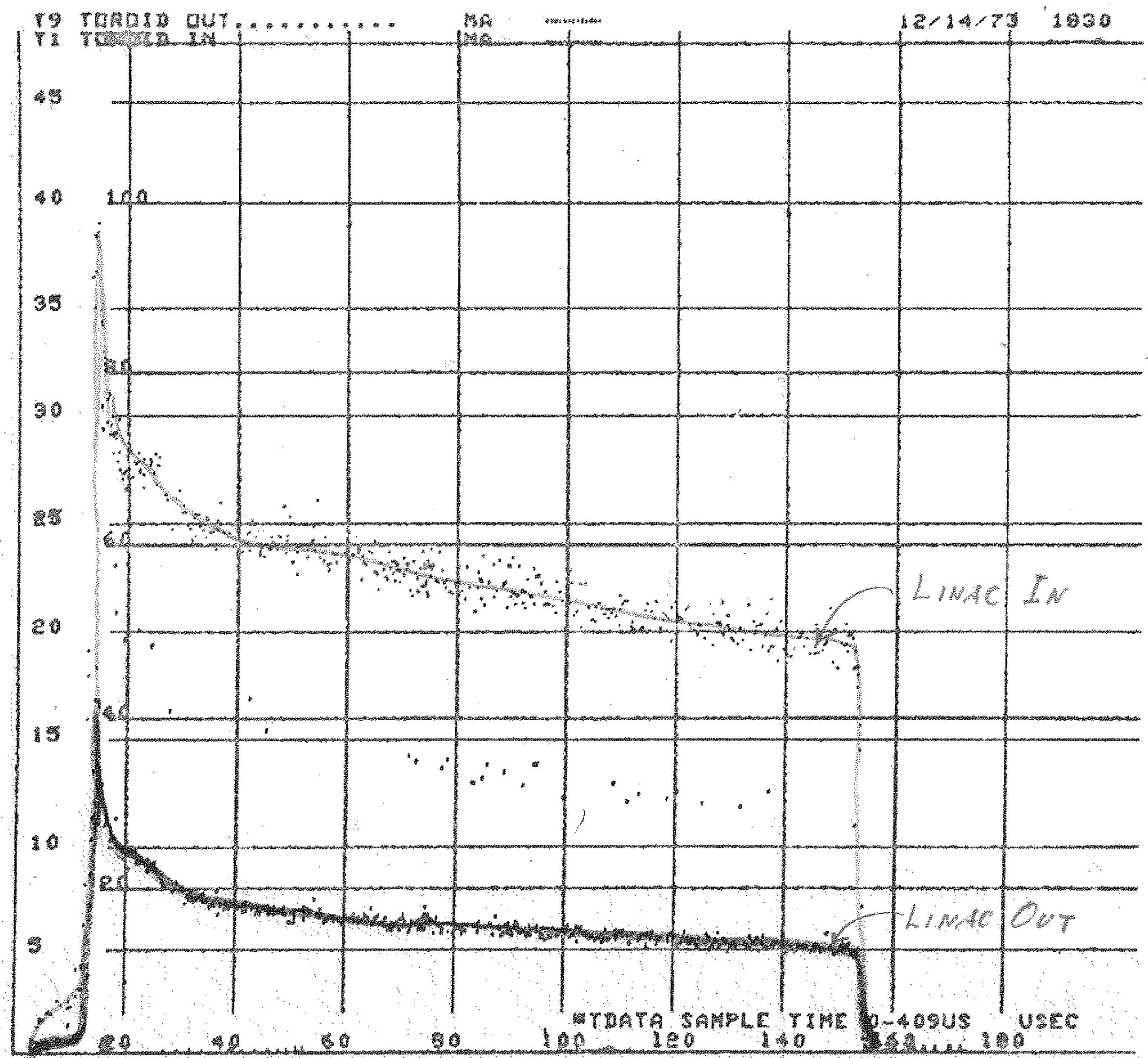
CDC/ss

5-10 mA



T9 TOROID OUT........... MA
T1 TOROID IN MA
12/14/73 1830
45
40
35
30
25
20
15
10
5
100
80
60
40
20
20 40 60 80 100 120 140 160 180
*TDATA SAMPLE TIME 0-409US USEC
LINAC IN
LINAC OUT

FIG. 1

10 mA

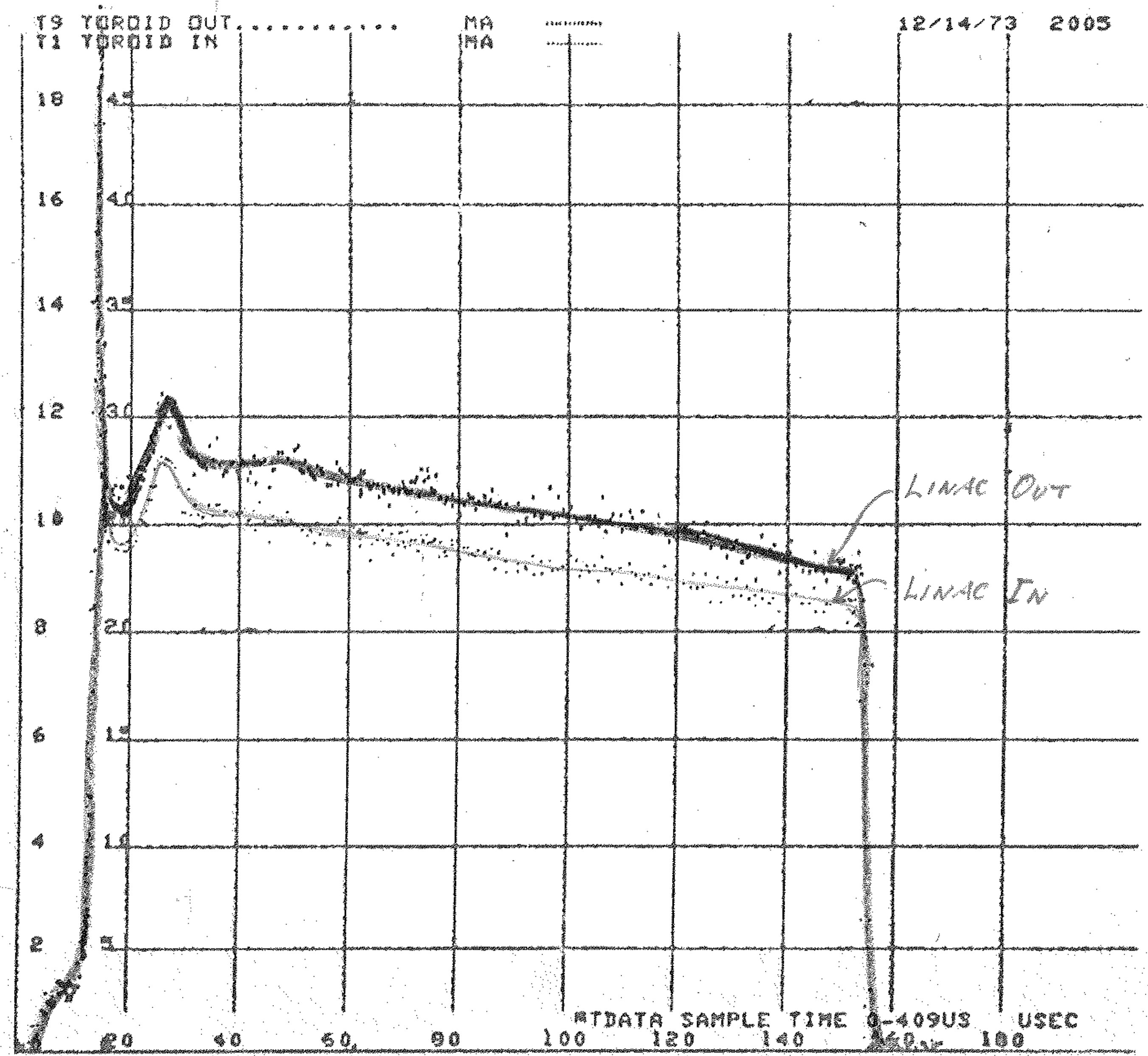
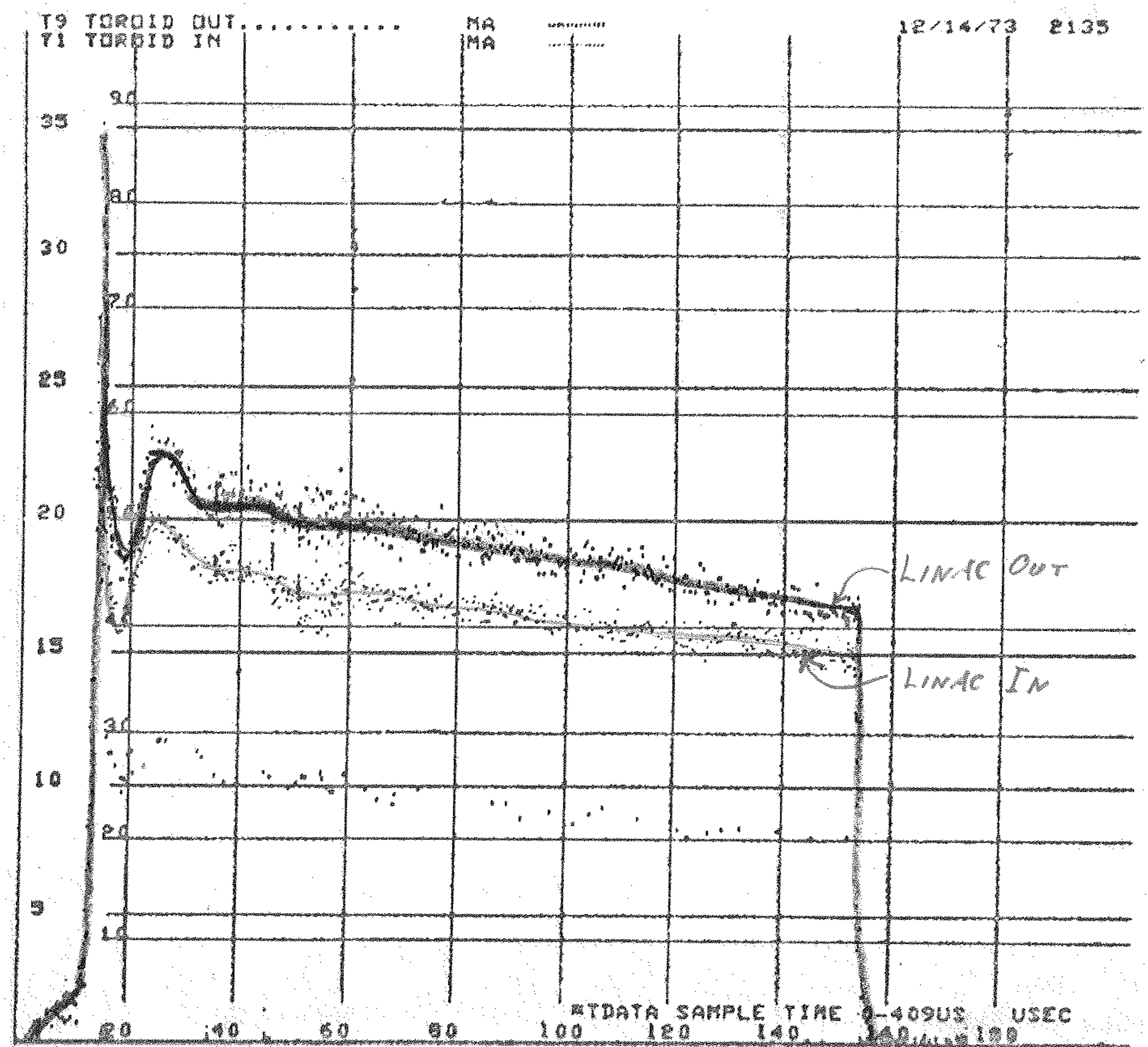

T9 TOROID OUT........... MA
T1 TOROID IN MA
12/14/73 2005
18
16
14
12
10
8
6
4
2
45
40
35
30
20
15
10
5
20
40
60
80
100
120
140
160
180
*TDATA SAMPLE TIME 0-409US USEC
LINAC OUT
LINAC IN

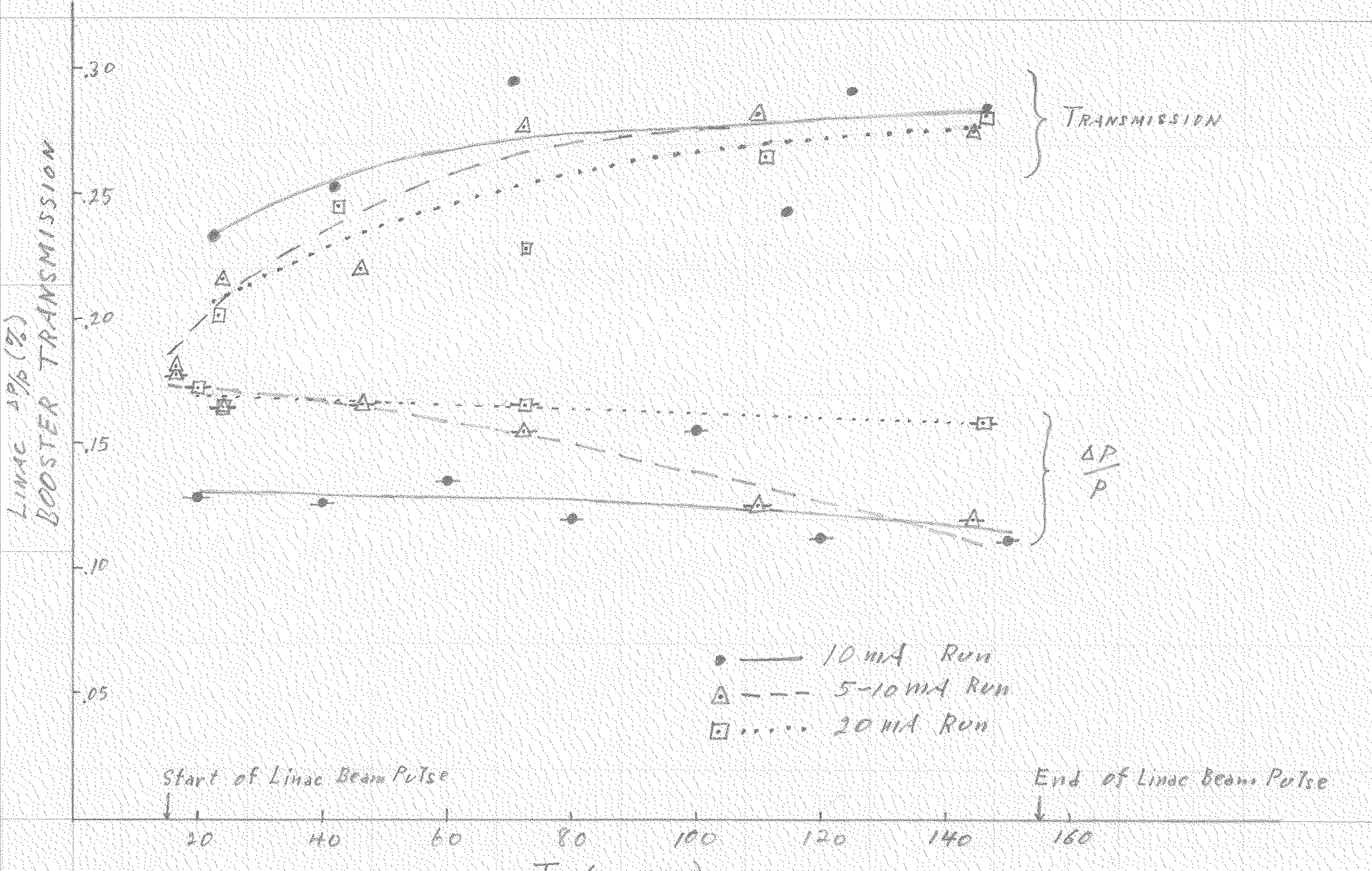
FIG.

20 MA



T9 TOROID OUT........... MA
T1 TOROID IN MA
12/14/73 2135
35
30
25
20
15
10
5
20
40
60
80
100
120
140
160
180
*TDATA SAMPLE TIME 0-409US USEC
LINAC OUT
LINAC IN

FIG. 9



LINAC Δp/p (%)
BOOSTER TRANSMISSION
.30
.25
.20
.15
.10
.05
TRANSMISSION
ΔP/P
10 mA Run
5-10 mA Run
20 mA Run
Start of Linac Beam Pulse
End of Linac Beam Pulse
20
40
60
80
100
120
140
160
TD (μsec)

FIG. 4.

80

Beam Current ≈ 10 mA

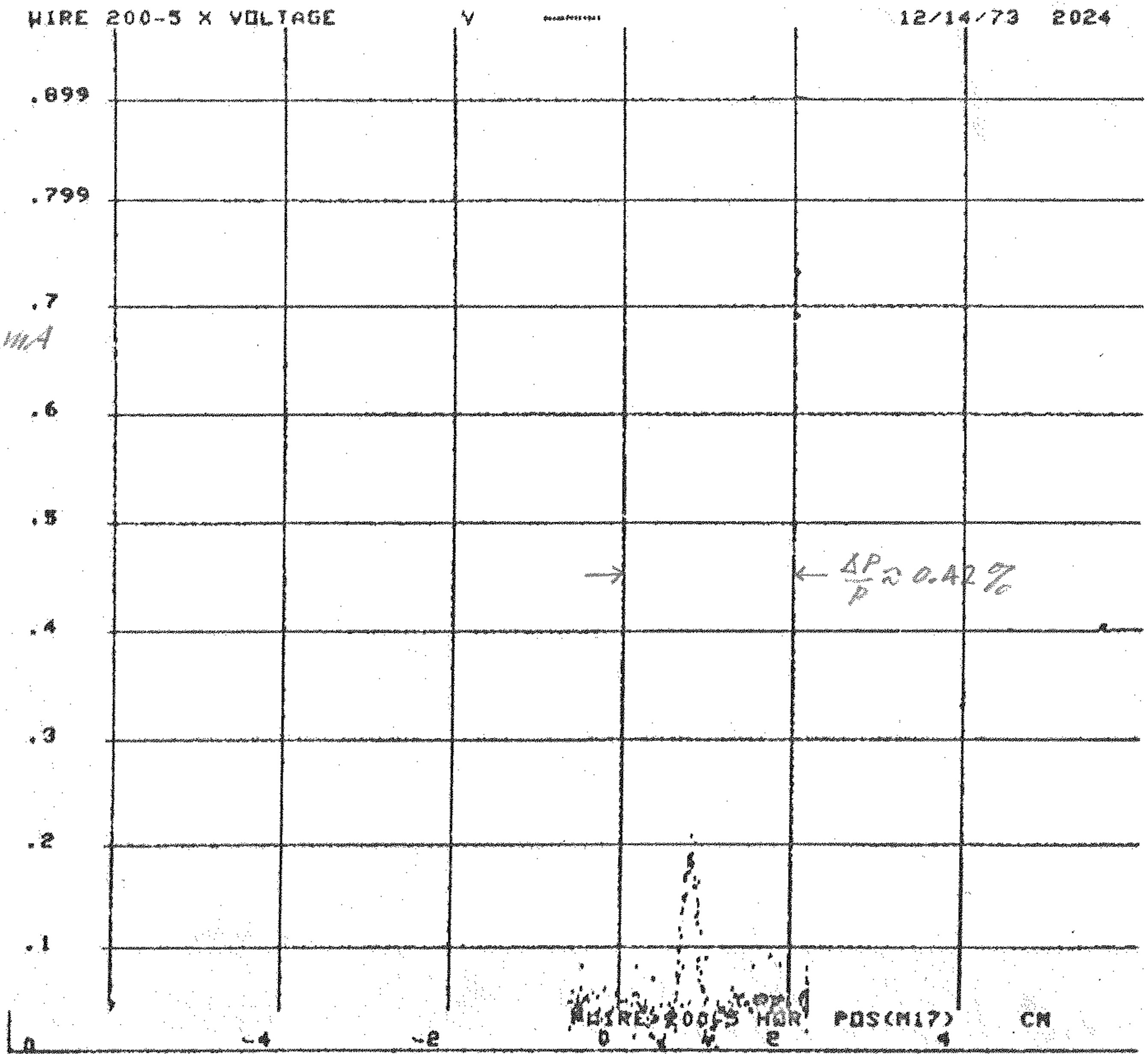


Fig. 5. LINAC MOMENTUM SPREAD

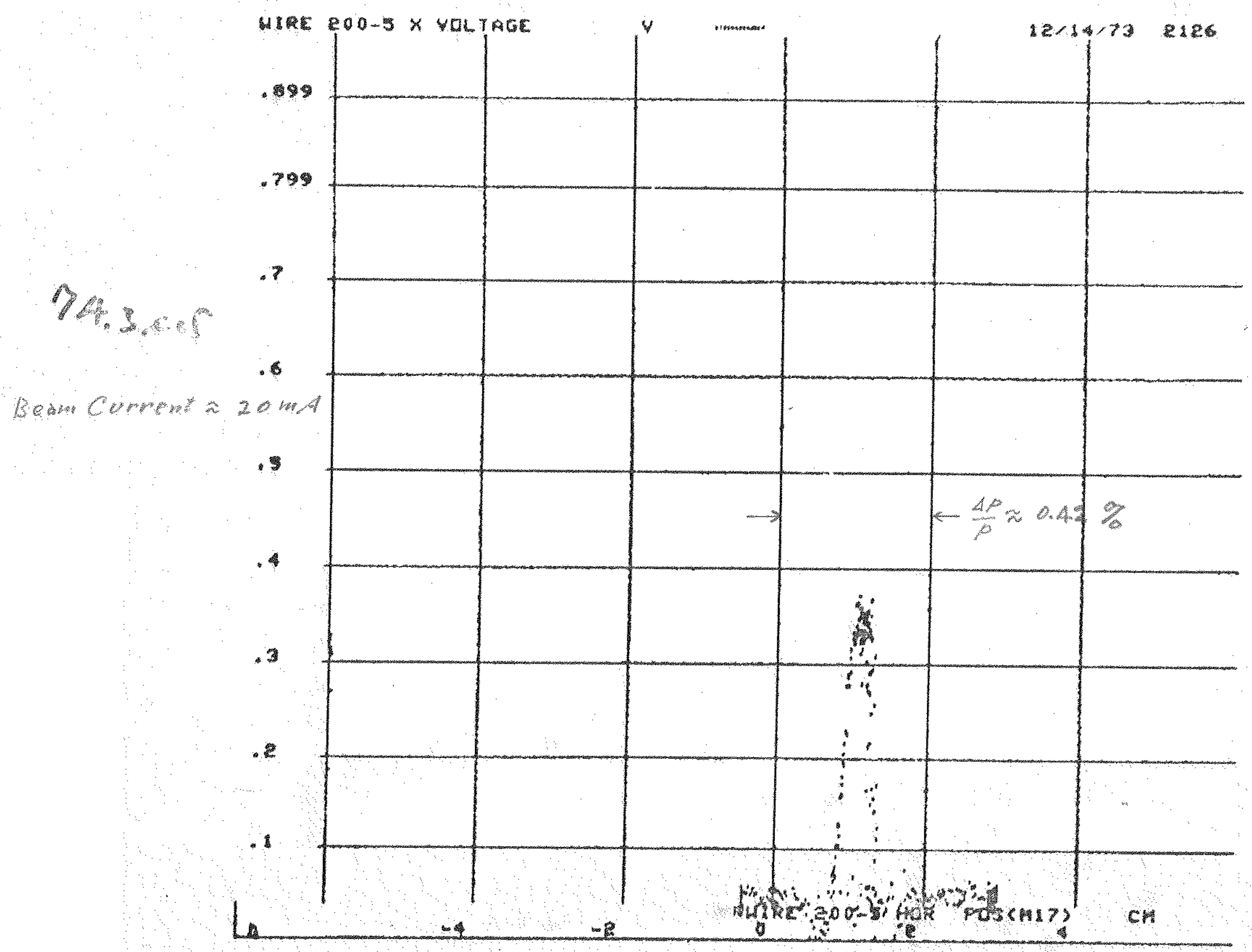


FIG 6. LINAC MOMENTUM SPREAD

TRANSMISSION OF 200-MEV LINE

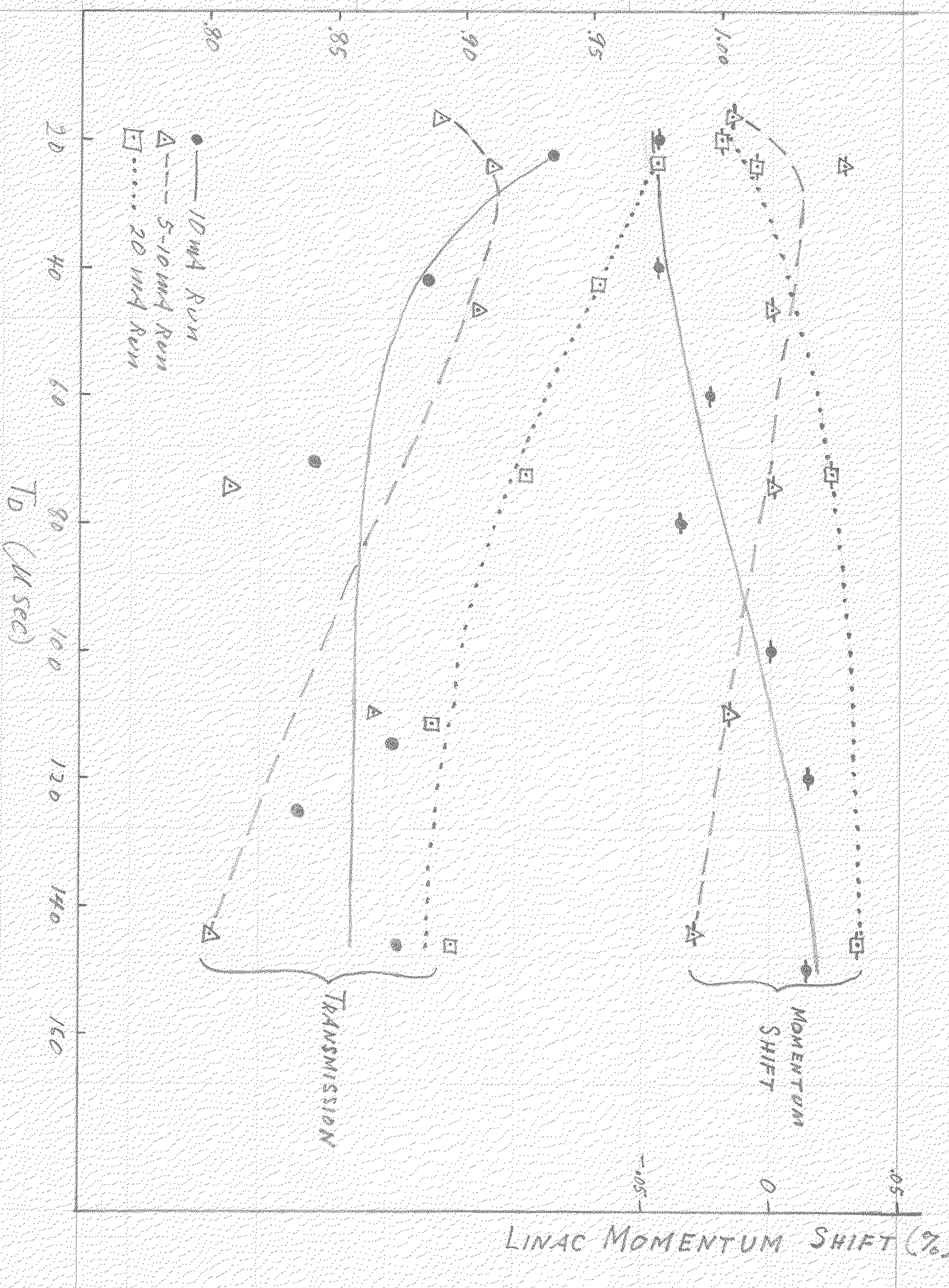


FIG. 7